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TECHNICAL REPORT

EP-156

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COMPOSITION AND CALORIC DENSITY OF WEIGHT
LOSS DURING CALORIC RESTRICTION IN THE COLD

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QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

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ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-156

COMPOSITION AND CALORIC DENSITY OF WEIGHT LOSS DURING
CALORIC RESTRICTION IN THE COLD

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FOREWORD

THE SIMPLEST METHOD FOR DETERMINING THE AMOUNT OF FOOD A SOLDIER REQUIRES IS TO PROVIDE HIM WITH SUFFICIENT FOOD TO MAINTAIN A CONSTANT WEIGHT AND TO MEASURE THE CALORIES CONSUMED. MANY OF THE ESTABLISHED REQUIREMENTS FOR CALORIES HAVE BEEN DERIVED FROM THIS SIMPLE APPROACH. WHEN, HOWEVER, A LOSS IN WEIGHT OCCURS DESPITE MORE THAN ADEQUATE AVAILABILITY OF FOOD, CALCULATIONS MUST BE MADE OF THE CALORIES WHICH THE BODY ITSELF HAS SUPPLIED IN TERMS OF TISSUE BREAKDOWN AND THE FINAL ESTIMATE OF CALORIC REQUIREMENTS MUST BE CORRECTED ACCORDINGLY. SUCH CORRECTIONS REQUIRE A RATHER PRECISE KNOWLEDGE OF HOW MANY CALORIES THE BODY TISSUES HAVE PROVIDED, I.E., THE CALORIC DENSITY OF THE WEIGHT LOST. THE PRESENT REPORT PROVIDES VALUES WHICH MAY BE USED FOR THIS PURPOSE WITH REASONABLE CONFIDENCE.

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ABSTRACT

TWO GROUPS OF 6 MEN EACH LIVED FOR 14 DAYS IN A COLD CHAMBER AT 60°F (15.6°C); ACTIVITY WAS SEDENTARY AND ONLY ATHLETIC SHORTS WERE WORN. DURING THIS PERIOD ONE GROUP (A) WAS SEMI-STARVED (600 KCAL/DAY) AND THE OTHER (B) WAS COMPLETELY STARVED (0 KCAL/DAY). CHANGES IN BODY COMPOSITION WERE MEASURED AND CALORIC DENSITY OF WEIGHT LOSS WAS CALCULATED. MEAN WEIGHT LOSS WAS 5.66 KG FOR A, AND 8.56 KG FOR B. COMPOSITION AND CALORIC DENSITY OF WEIGHT LOSS WAS ALMOST IDENTICAL FOR BOTH GROUPS. COMPOSITION OF WEIGHT LOSS WITH REGARD TO FAT, PROTEIN, AND WATER WAS: 39, 10, AND 51% FOR A; 39, 11, AND 49% FOR B. CALORIC DENSITY WAS 3.91 KCAL/GM FOR A AND 4.06 KCAL/GM FOR B.

COMPOSITION AND CALORIC DENSITY OF WEIGHT LOSS DURING CALORIC RESTRICTION IN THE COLD

1. INTRODUCTION

ESTIMATES OF MAN'S DAILY CALORIC REQUIREMENTS MAY BE MADE WITH REASONABLE VALIDITY IF THE BODY COMPOSITION AND WEIGHT DO NOT CHANGE DURING THE EXPERIMENTAL PERIOD. THIS MAY BE DONE SIMPLY BY CAREFUL MEASUREMENT OF DAILY CALORIC INTAKE. IF, HOWEVER, CHANGES IN BODY WEIGHT AND/OR COMPOSITION OCCUR, CORRECTIONS MUST BE MADE FOR THE CALORIC EQUIVALENT OF THE TISSUE EXCHANGES. VALUES FOR THE CALORIC EQUIVALENT OF WEIGHT CHANGES HAVE BEEN REPORTED WHICH RANGE FROM 2.5 TO 6.2 OR MORE KCAL/GM (1, 2). THIS VARIABILITY INDICATES THAT APPRECIABLE UNCERTAINTIES MAY ATTEND CALCULATIONS OF CALORIC REQUIREMENTS WHEN LARGE CHANGES IN WEIGHT OCCUR.

AN OPPORTUNITY WAS PRESENTED RECENTLY TO MEASURE CHANGES IN BODY COMPOSITION AND, THUS, TO CALCULATE VALUES FOR THE CALORIC EQUIVALENT OF THE WEIGHT LOST DURING TWO STUDIES IN WHICH MEN WERE FED, RESPECTIVELY, 600 AND 0 KCAL/DAY FOR 14 DAYS. THIS REPORT PRESENTS THE RESULTS OF THESE STUDIES.

2. EXPERIMENTAL DESIGN AND METHODS

TWO STUDIES WERE PERFORMED. IN THE FIRST (STUDY A), 6 YOUNG MEN LIVED IN A CHAMBER MAINTAINED AT 60°F (15.6°C) FOR 2 WEEKS. AIR MOVEMENT WAS APPROXIMATELY 40 FT/MIN; RELATIVE HUMIDITY WAS 50%. DURING THIS PERIOD THEY WERE NUDE EXCEPT FOR COTTON SHORTS AND SOCKS AND WERE ENGAGED ONLY IN MINIMAL, SEDENTARY ACTIVITY, E.G., CARD-PLAYING, READING, WRITING, WATCHING TV. EACH SUBJECT WAS PERMITTED ONE ARMY WOOLEN BLANKET DURING THE NIGHT. CALORIC INTAKE WAS RESTRICTED TO 600 KCAL/MAN/DAY. THIS WAS IN THE FORM OF A MILK DRINK SERVED IN EQUAL PORTIONS 3 TIMES DAILY. THE COMPOSITION OF THIS DRINK WAS AS FOLLOWS: CARBOHYDRATE 41%, PROTEIN 17%, FAT 42%, CALORIC DENSITY 1.2 KCAL/GM. THE EXPERIMENTAL PERIOD WAS PRECEDED BY 2 WEEKS AT 80°F (26.7°C), DURING WHICH TIME SUFFICIENT CALORIES IN THE FORM OF THE ABOVE-MENTIONED MILK DRINK PLUS TOAST AND BUTTER WERE PROVIDED TO MAINTAIN BODY WEIGHT. DURING THIS CONTROL PERIOD A MULTI-VITAMIN SUPPLEMENT WAS GIVEN MORNING AND EVENING.

IN THE SECOND (STUDY B), ALL CONDITIONS WERE IDENTICAL WITH THOSE OF STUDY A EXCEPT THAT DURING THE COLD PERIOD NO CALORIES WERE PROVIDED, I.E., COMPLETE STARVATION PREVAILED. IN STUDY B THE TEST SUBJECTS WERE 6 MEN WHO WERE NOT INVOLVED IN STUDY A.

THE MEAN AGES OF THE 2 GROUPS WERE 19.7 AND 21.2 YEARS AND THE MEAN WEIGHTS WERE 69.3 AND 70.3 KG, RESPECTIVELY. WATER WAS PERMITTED AD LIBITUM, AND 4 CUPS OF HOT COFFEE, WITHOUT CREAM OR SUGAR, WERE SERVED DAILY IN BOTH STUDIES.

BODY SPECIFIC GRAVITIES OF THE TEST SUBJECTS WERE DETERMINED ON THE DAY PRECEDING AND AGAIN ON THE DAY FOLLOWING THE 2 WEEKS OF CALORIC RESTRICTION. THIS WAS DETERMINED BY WEIGHING THE TEST SUBJECTS IN AIR AND WHILE COMPLETELY SUBMERGED IN WATER, USING A WATER TANK SIMILAR TO THAT DESCRIBED BY VON DÖBELN (3) AND CORRECTING FOR RESIDUAL LUNG VOLUME BY NITROGEN DILUTION AS DESCRIBED ELSEWHERE (4). FROM THESE DETERMINATIONS THE BODY FAT CONTENTS OF THE TEST SUBJECTS WERE CALCULATED. NITROGEN BALANCES WERE DETERMINED AND, FROM THE CUMULATIVE NEGATIVE BALANCE, THE AMOUNT OF FAT-FREE TISSUE LOST WAS DETERMINED. NUDE BODY WEIGHTS WERE DETERMINED EACH MORNING AFTER THE TEST SUBJECTS HAD VOIDED.

FROM THE MEASUREMENTS DESCRIBED ABOVE IT WAS POSSIBLE TO CALCULATE THE RELATIVE CONTRIBUTIONS OF FAT AND PROTEIN TO THE TOTAL WEIGHT LOSS OVER THE PERIODS OF CALORIC RESTRICTION, AND THUS TO CALCULATE THE CALORIC EQUIVALENT OF THE WEIGHT LOST.

3. RESULTS

A. WEIGHT LOSS

WEIGHTS AT THE BEGINNING AND END OF BOTH STUDIES ARE SHOWN IN TABLE I. MEAN WEIGHT LOSSES WERE 5.66 AND 8.56 KG FOR GROUPS A AND B, RESPECTIVELY. THE PATTERN OF DAILY WEIGHT LOSS WAS SIMILAR FOR BOTH GROUPS; AFTER THE FIRST 2 DAYS, THE DAILY WEIGHT LOSS WAS ESSENTIALLY LINEAR (FIG. 1). THUS, DURING THE LAST 12 DAYS GROUP A SHOWED A DAILY WEIGHT LOSS OF 0.317 KG/DAY AND GROUP B LOST 0.525 KG/DAY. THE COMPARATIVELY LARGE WEIGHT LOSS DURING THE FIRST 2 DAYS OF THE EXPERIMENTAL PERIODS (1.9 AND 2.3 KG/MAN/DAY FOR STUDIES A AND B) WILL BE DISCUSSED BELOW.

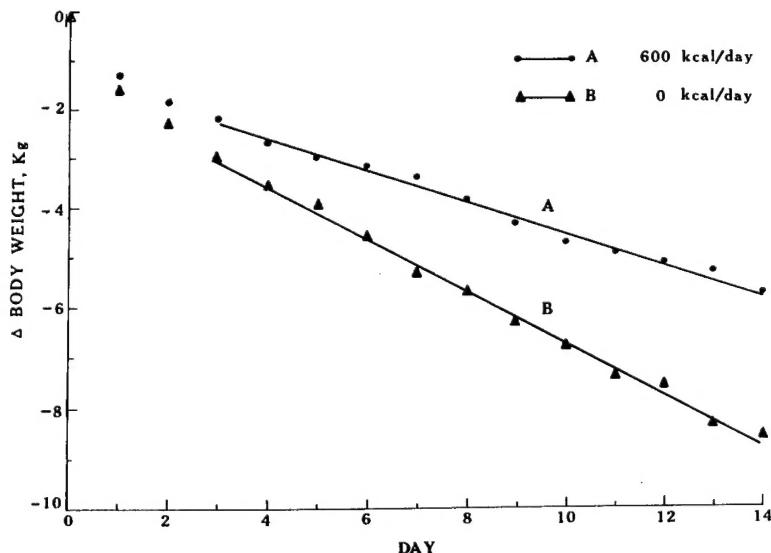


FIGURE 1: DAILY WEIGHT LOSS DURING CALORIC RESTRICTION IN THE COLD (MEANS OF 6 MEN).

B. COMPOSITION OF WEIGHT LOSS

FOR THE PURPOSE OF THIS REPORT, THE COMPOSITION OF THE WEIGHT LOST WILL BE EXPRESSED IN TERMS OF FAT, PROTEIN, AND WATER. FAT AND PROTEIN LOSSES WERE CALCULATED FROM CHANGES IN BODY SPECIFIC GRAVITY AND FROM CUMULATIVE NEGATIVE NITROGEN BALANCES, RESPECTIVELY. THE DIFFERENCE BETWEEN THE TOTAL WEIGHT LOSS AND THE SUM OF FAT AND PROTEIN LOST IS HERE TERMED "WATER." IT IS REALIZED, OF COURSE, THAT A MOIETY OF THIS "WATER" IS REPRESENTED BY ELECTROLYTES AND GLYCOGEN STORES. THE ELECTROLYTES REPRESENT A NEGLIGIBLE FRACTION OF WEIGHT LOSS AND PROVIDE NO CALORIES. GLYCOGEN MAY HAVE ACCOUNTED FOR AS MUCH AS 150 GRAMS OF THE WEIGHT LOSS, REPRESENTING A TOTAL OF 634 CALORIES (5); FAILURE TO TAKE THIS INTO ACCOUNT REPRESENTS AN ERROR OF 5% OF WATER LOSS IN STUDY A AND 3.8% IN STUDY B. TABLE I SHOWS THAT ALTHOUGH THE ABSOLUTE AMOUNTS OF FAT, PROTEIN, AND WATER LOST IN STUDY A WERE SMALLER THAN IN STUDY B, THE CONTRIBUTION TO THE TOTAL WEIGHT LOSS OF EACH OF THESE COMPONENTS IS REMARKABLY SIMILAR FOR BOTH STUDIES: 39% AND 39% FOR FAT, 10% AND 11% FOR PROTEIN, 51% AND 49% FOR "WATER." THESE VALUES ARE IN CLOSE AGREEMENT WITH THOSE OF BROZEK, ET AL (5) IF THEIR VALUES ARE AVERAGED FOR A 12-DAY PERIOD.

THE TOTAL AMOUNTS OF PROTEIN, FAT, AND WATER LOST IN STUDIES A AND B WERE: PROTEIN, 0.52 KG AND 0.96 KG; FAT, 2.15 AND 3.31 KG; "WATER," 3.00 AND 4.29 KG, RESPECTIVELY (TABLE 1).

C. CALORIC VALUE OF WEIGHT LOSS

STANDARD VALUES FOR THE CALORIC EQUIVALENT OF PROTEIN (4.1 KCAL/GM) AND FAT (9.3 KCAL/GM) WERE USED IN CALCULATING THE CALORIES DERIVED FROM TISSUE BREAKDOWN (TABLE II). THUS CALCULATED, FAT WAS THE SOURCE OF 90.3% OF THE CALORIES IN STUDY A, AND 88.6% OF THOSE IN STUDY B. PROTEIN PROVIDED 9.7 AND 11.4% IN STUDIES A AND B, RESPECTIVELY. IT IS INTERESTING THAT, DESPITE THE FACT THAT THE WEIGHT LOSS IN STUDY B WAS 51% GREATER THAN IN STUDY A, THE RELATIVE CONTRIBUTIONS OF FAT AND PROTEIN WERE QUITE SIMILAR IN BOTH STUDIES. THE TOTAL CALORIES REALIZED FROM TISSUE BREAKDOWN (EXCLUDING GLYCOGEN) WAS 22,131 KCAL IN STUDY A AND 34,727 KCAL IN STUDY B. CALORIC DENSITY OF WEIGHT LOSS, CALCULATED FROM TOTAL CALORIES AND WEIGHT LOSS, WAS ESSENTIALLY THE SAME FOR BOTH STUDIES, STUDY A = 3.91 KCAL/GM; STUDY B = 4.06 KCAL/GM (TABLE II).

4. DISCUSSION

THE ASSESSMENT OF CALORIC DENSITY OF WEIGHT LOSS IS COMPLICATED, ON THE ONE HAND BY DIFFICULTIES IN THE TECHNIQUES OF MEASURING THE COMPOSITION OF THE LOST WEIGHT, AND ON THE OTHER HAND, BY THE FACT THAT THE MIXTURE OF TISSUES WHICH ARE "CANNIBALIZED" TO SUPPLY CALORIES IS NOT FIXED, BUT VARIES WITH THE DURATION AND SEVERITY OF CALORIC RESTRICTION. VALUES BASED ON ESTIMATES OF ENERGY EXPENDITURE AND/OR CALORIC INTAKE MAY LEAD TO LARGE ERRORS UNLESS THE INTAKES AND EXPENDITURES ARE ADEQUATELY AND ACCURATELY MEASURED OR CONTROLLED DURING THE ENTIRE EXPERIMENTAL PERIOD; THIS IS INDEED A MOST DIFFICULT TASK. IF ESTIMATES OF CALORIC DEFICIT

TABLE I

COMPOSITION OF WEIGHT LOSS DURING 2 WEEKS OF CALORIC RESTRICTION

SUBJECT	BODY WEIGHT (KG)			BODY FAT (KG)			PROTEIN LOST (KG)			COMPOSITION OF WEIGHT LOSS (%)		
	PRE	POST	Δ	PRE	POST	Δ	PROTEIN LOST (KG)	FAT	TEIN	FAT	TEIN	"WATER"
STUDY A (600 KCAL/DAY)												
1	71.54	65.14	-6.40	17.16	15.36	-1.80	0.43	4.17	27.7	6.6	65.7	
2	58.39	53.78	-4.61	5.88	2.80	-3.08	0.54	0.99	61.6	10.9	27.5	
3	75.53	69.85	-5.68	16.98	14.42	-2.56	0.52	2.60	49.2	10.0	40.8	
4	67.10	61.59	-5.51	12.78	11.53	-1.25	0.51	3.75	25.0	10.2	64.8	
5	76.34	70.09	-6.25	15.50	13.61	-1.89	0.59	3.77	34.4	10.6	55.0	
6	67.17	61.64	-5.53	13.91	11.62	-2.29	0.54	2.70	39.5	9.3	51.2	
MEAN	69.34	63.68	-5.66	13.70	11.55	-2.15	0.52	3.00	39.1	9.5	51.4	
STUDY B (0 KCAL/DAY)												
1	71.66	63.14	-8.52	17.57	14.62	-2.95	0.88	4.69	36.0	10.7	53.3	
2	69.24	60.71	-8.53	15.65	12.79	-2.86	1.10	4.57	32.9	12.6	54.5	
3	65.72	56.92	-8.80	11.74	7.55	-4.19	0.89	3.72	48.7	10.3	41.0	
4	64.45	56.87	-7.58	9.21	5.75	-3.46	1.03	3.09	44.9	13.4	41.7	
5	71.28	62.32	-8.96	13.74	10.34	-3.40	1.02	4.54	38.2	11.5	50.3	
6	79.18	70.20	-8.98	15.48	12.48	-3.00	0.85	5.13	35.3	10.0	54.7	
MEAN	70.26	61.69	-8.56	13.90	10.59	-3.31	0.96	4.29	39.4	11.4	49.2	

TABLE II
CALORIC DENSITY OF WEIGHT LOSS

	<u>GROUP</u>	
	<u>A</u>	<u>B</u>
TOTAL WEIGHT LOSS (KG)	5.66	8.56
(A) PROTEIN (KG)	0.52	0.96
(B) FAT (KG)	2.15	3.31
CALORIC EQUIVALENT OF PROTEIN (KCAL)	2,136	3,944
CALORIC EQUIVALENT OF FAT (KCAL)	19,995	30,783
TOTAL CALORIES	22,131	34,727
CALORIC DENSITY OF WEIGHT LOSS (KCAL/GM)	3.91	4.06

ARE BASED ON THE DIFFERENCES BETWEEN CALORIC INTAKE DURING A PERIOD OF "BODY WEIGHT MAINTENANCE" AND THE INTAKE DURING THE RESTRICTION PERIOD, THE ASSUMPTION MUST BE MADE THAT ENERGY EXPENDITURE WAS THE SAME FOR BOTH PERIODS. THIS ASSUMPTION IS NOT CORRECT (6).

THE MORE DIRECT APPROACH IS TO DETERMINE BODY FAT CONTENT BEFORE AND AFTER A PERIOD OF RESTRICTION AND AT THE SAME TIME CALCULATE PROTEIN BREAKDOWN FROM THE MEASURED NEGATIVE NITROGEN BALANCE. THIS METHOD WAS USED IN THE PRESENT STUDY WHICH HAS THE FOLLOWING ADDITIONAL ADVANTAGES:
(A) CONTROLLED ACTIVITY, WHICH VARIED MINIMALLY DURING ANY GIVEN DAY OR FROM DAY TO DAY; (B) CONTROLLED ENVIRONMENT; (C) MINIMAL FECAL PRODUCTION.

OUR RESULTS, AS WELL AS THOSE OF OTHER WORKERS (5, 7) SHOW THAT RELATIVELY LARGE AMOUNTS OF WATER ARE LOST DURING THE FIRST DAYS OF CALORIC RESTRICTION. SINCE, IN THE PRESENT STUDY, THE MEN WERE EXPOSED TO COLD, THE EARLY WEIGHT LOSSES ARE IN PART THE RESULT OF COLD DIURESIS. IN A SIMILAR STUDY WITH ADEQUATE CALORIES, IT WAS FOUND THAT THE CUMULATIVE NEGATIVE WATER BALANCE WAS ONLY 0.3 LITERS DURING THE FIRST 4 DAYS (8). ESTIMATES OF THE "CALORIC VALUE" OF THE WEIGHT LOSS DURING SHORT-TERM (1 TO 4 DAYS) STUDIES ARE USUALLY LOW (2,5) DUE TO THE HIGH PROPORTION OF WATER IN THE WEIGHT LOST. CURVES OF WEIGHT LOSS FURTHER INDICATE THAT THE WEIGHT LOSS (AND WATER LOSS) IN THE FIRST DAYS OF RESTRICTION IS NOT CONSTANT AND THIS LEADS TO INCREASED VARIABILITY IN THE ESTIMATION OF THE CALORIC DENSITY OF WEIGHT CHANGES. STUDIES WHICH ARE CONDUCTED OVER LONGER PERIODS OF TIME OBFVATE AT LEAST ONE OF THESE DIFFICULTIES, I.E., AFTER THE FIRST 2 OR 3 DAYS OF RESTRICTION, WEIGHT LOSS CURVES ARE NEARLY LINEAR (FIG. 1) ALTHOUGH THE PROPORTION OF FAT, PROTEIN, AND WATER IN THE WEIGHT LOST MAY STILL VARY FROM DAY TO DAY (5). DURING LONG-TERM STUDIES, THEREFORE, THE IMPACT OF THE LARGE WEIGHT (WATER) LOSSES DURING THE FIRST DAYS IS MINIMIZED.

OUR RESULTS ARE IN CLOSE AGREEMENT WITH THOSE RECENTLY REPORTED BY BROZEK, ET AL (5), USING LESS DIRECT TECHNIQUES. IN 2 STUDIES OF CALORIC RESTRICTION (580 KCAL/DAY AND 1010 KCAL/DAY) AND WITH THEIR SUBJECTS PERFORMING MODERATE ACTIVITY, THEY ARRIVED AT VALUES OF 4.3 AND 4.7 KCAL/GM OF WEIGHT LOSS OVER A 12-DAY PERIOD. IN THE PRESENT STUDIES THE VALUES FOR THE CALORIC DENSITY OF THE WEIGHT LOSS WERE 3.91 AND 4.06 KCAL/GM OVER A 14-DAY PERIOD. THIS INDICATES THAT THE COMPOSITION OF THE WEIGHT LOSS IS QUITE SIMILAR OVER A WIDE RANGE OF RATES AT WHICH WEIGHT IS LOST.

5. ACKNOWLEDGMENTS

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